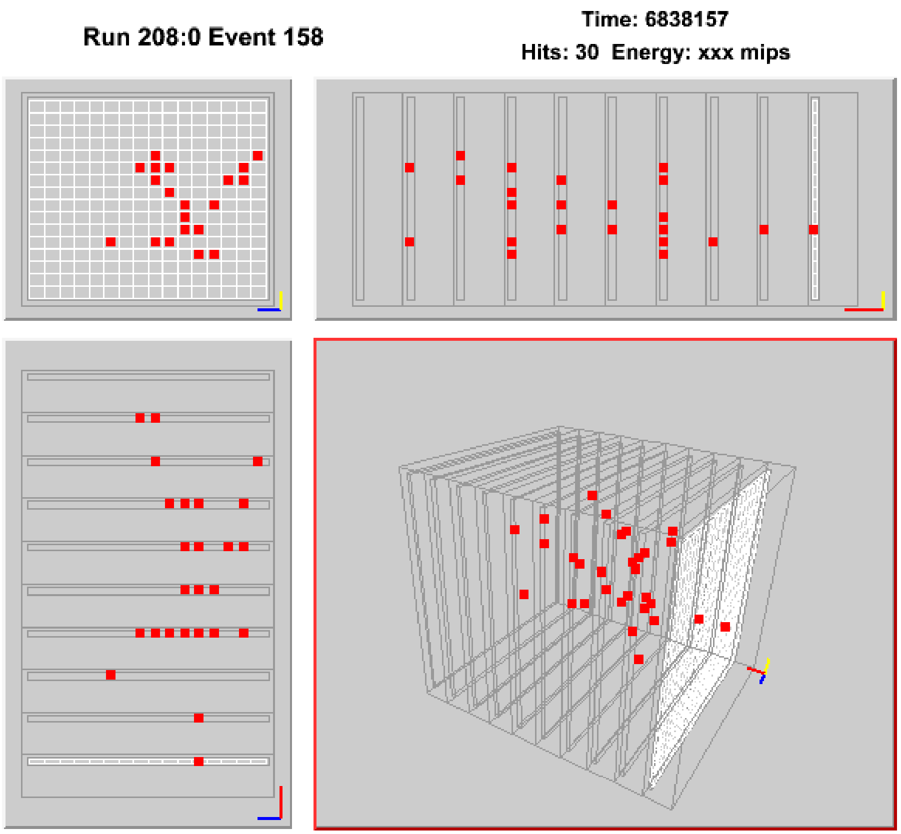
Analysis of Pion Data from the Vertical Slice Test of the RPC-DHCAL



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CALICE Meeting, Argonne, 17 – 19 March, 2008

Data with secondary beams

No noticable differences between runs within a setting

Analysis only of layers 0 – 5 (to be consistent) → 6.8 X_0 or 0.7 λ_I

Positrons

Trigger = coincidence of 2 19 x 19 cm^2 scintillation counters and one Čerenkov

Momentum	Run number	RPCs	Number of events
16 GeV/c	701	0 – 6	6540
8 GeV/c	702	0 – 5	39376
4 GeV/c	703	0 – 5	13061
2 GeV/c	262	0 – 5	8544
1 GeV/c	270	0 – 8	10599

Unknown mixture →

Pions/muons

Trigger = coincidence of 2 19 x 19 cm^2 scintillation counters vetoed by the .or. Of 2 Čerenkov counters

Momentum	Run number	RPCs	Number of events
16 GeV/c	801	0 – 5	29889
8 GeV/c	802	0 – 5	30657
4 GeV/c	261	0 – 5	5941
2 GeV/c	803	0 – 5	5642
	268 (bricks)	0 – 8	1068
1 GeV/c	269	0 – 8	1378

Brick Run at 2 GeV/c

Additional stack of Iron blocks

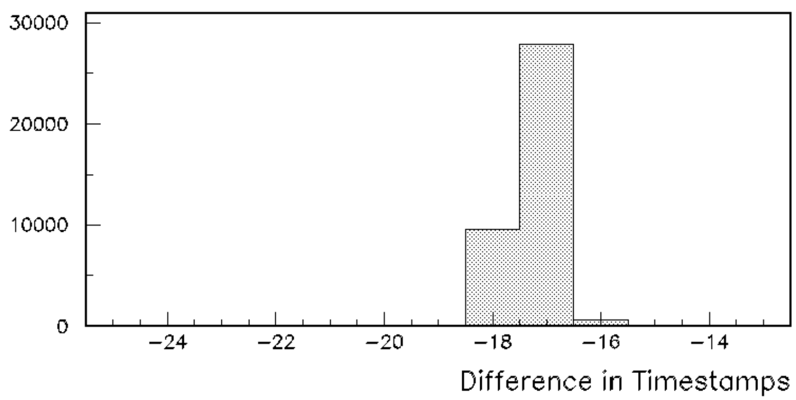
50 cm deep corresponding to 3 λ_I
→ 97% of π interact
→ ΔE_μ ~ 600 MeV

Data Quality

e.g. Run 235

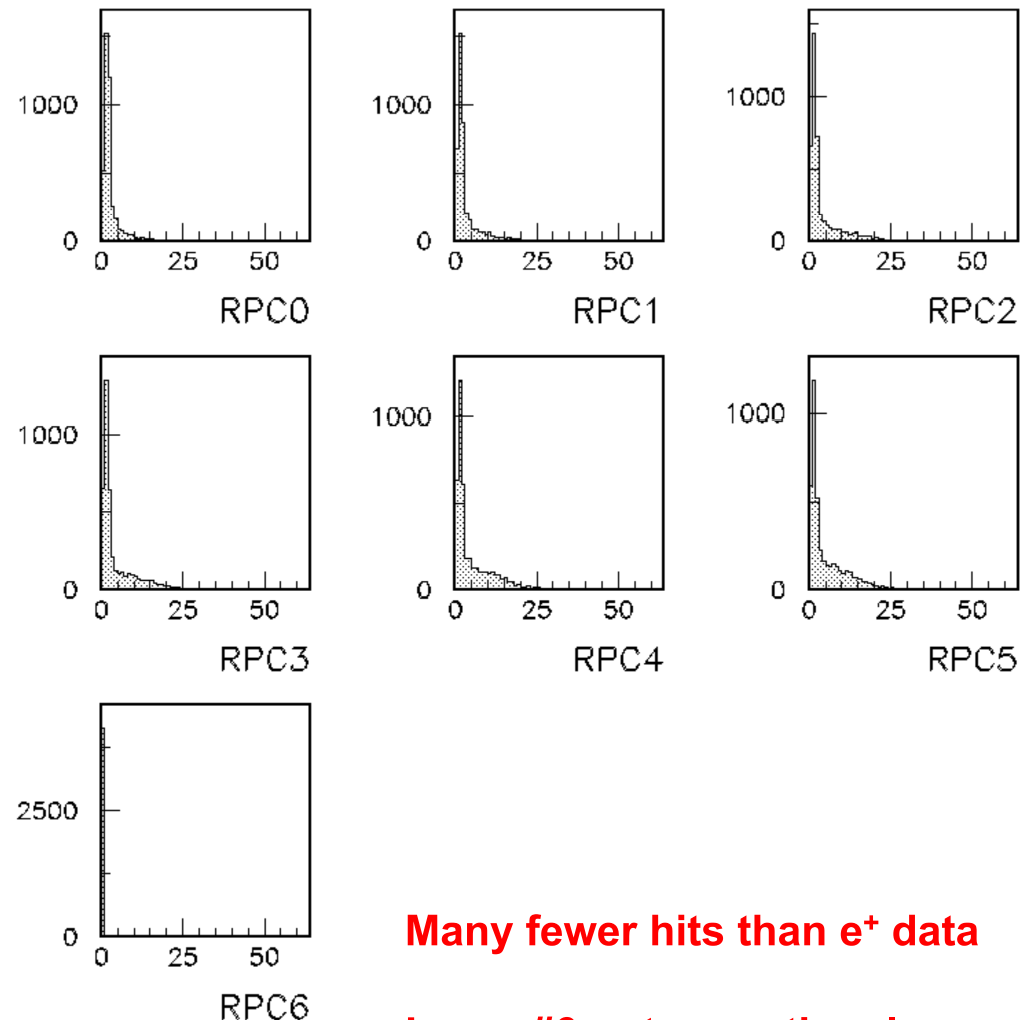
Difference of data time-stamps
with trigger time-stamp

Each bin 100 ns



Looks good!

Number of hits

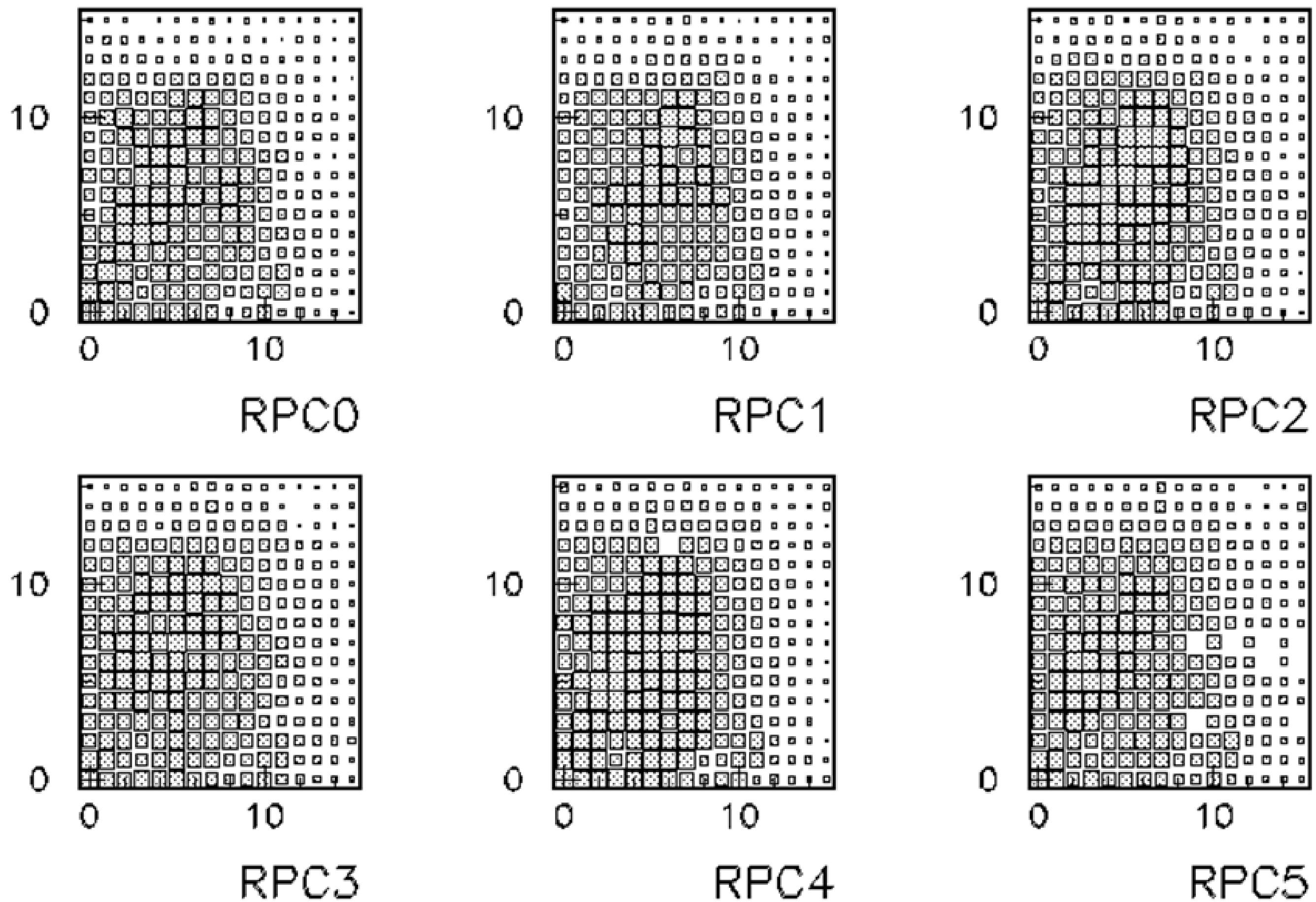


Many fewer hits than e^+ data

Layer #6 not operational

x – y Map of Hits

Not centered on calorimeter
Due to creepy table

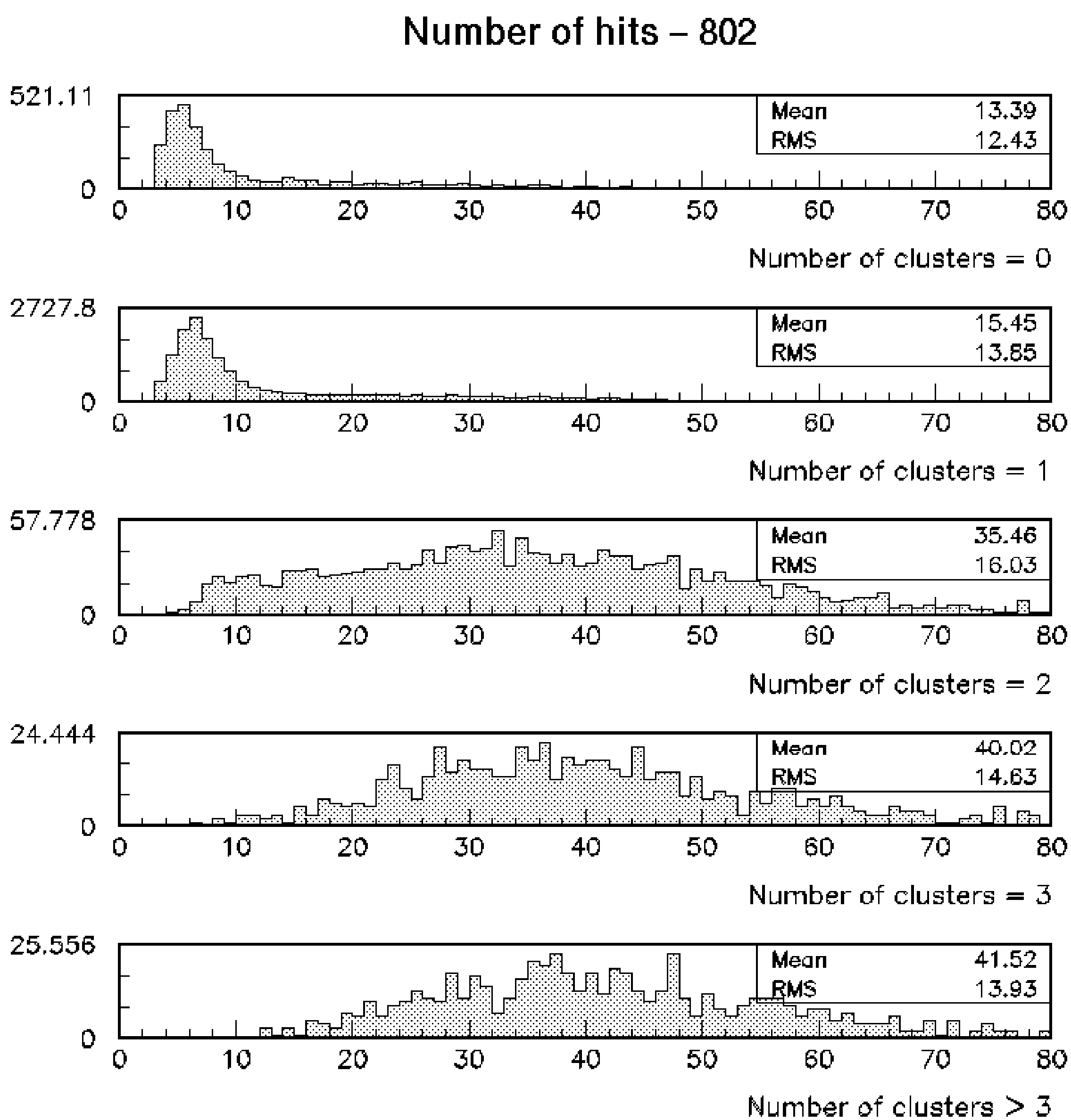


Hits distributed over large area

→ requires fiducial cut

Clusters in first layer

Data selection:	All data



Some loss when no hits in first layer: biased efficiency?

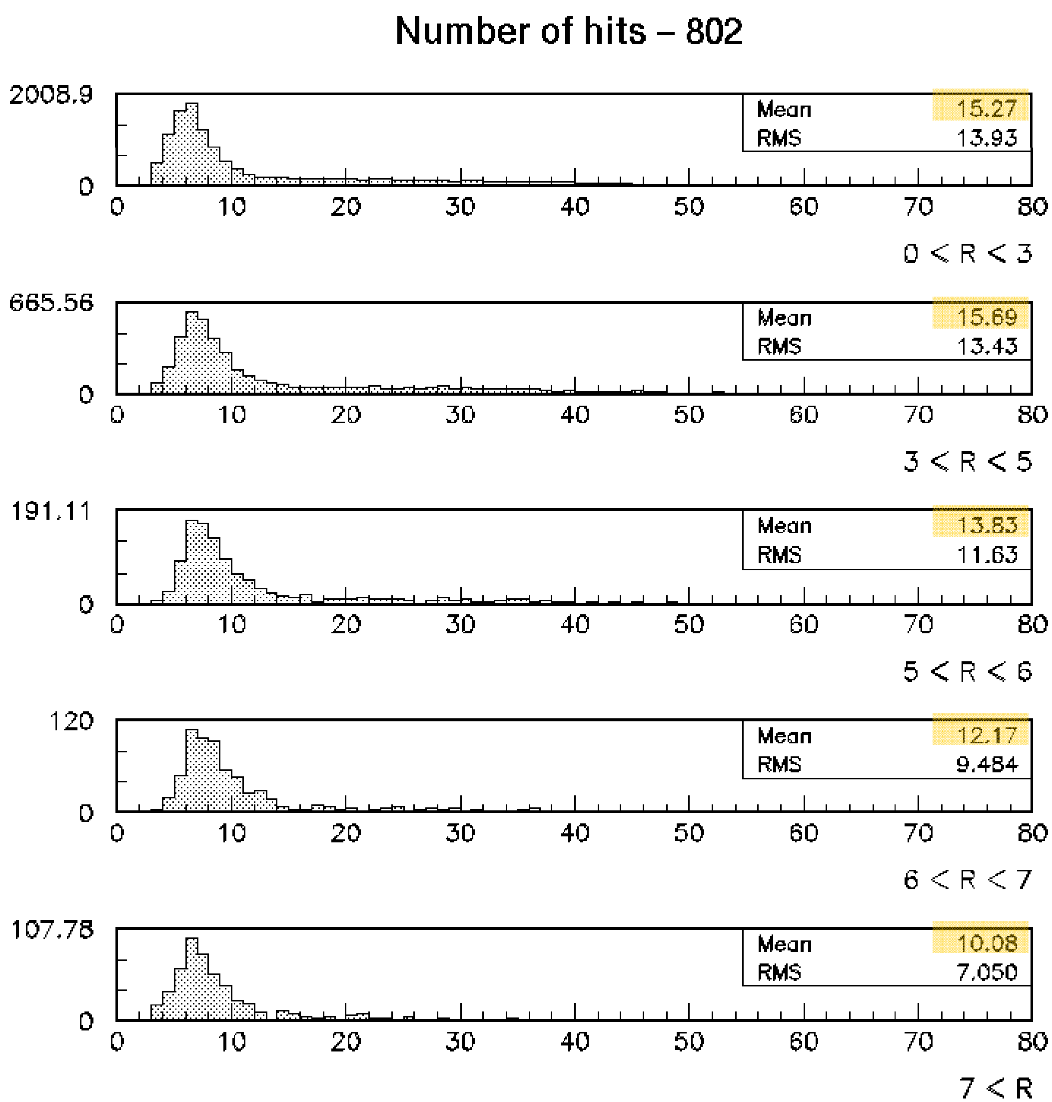
~ 2000 events

Look mostly like upstream hadronic showers

Positron peak
$\mu \pm \sigma = 49 \pm 10$

Fiducial cuts

Data selection:	Request exactly one cluster in first layer



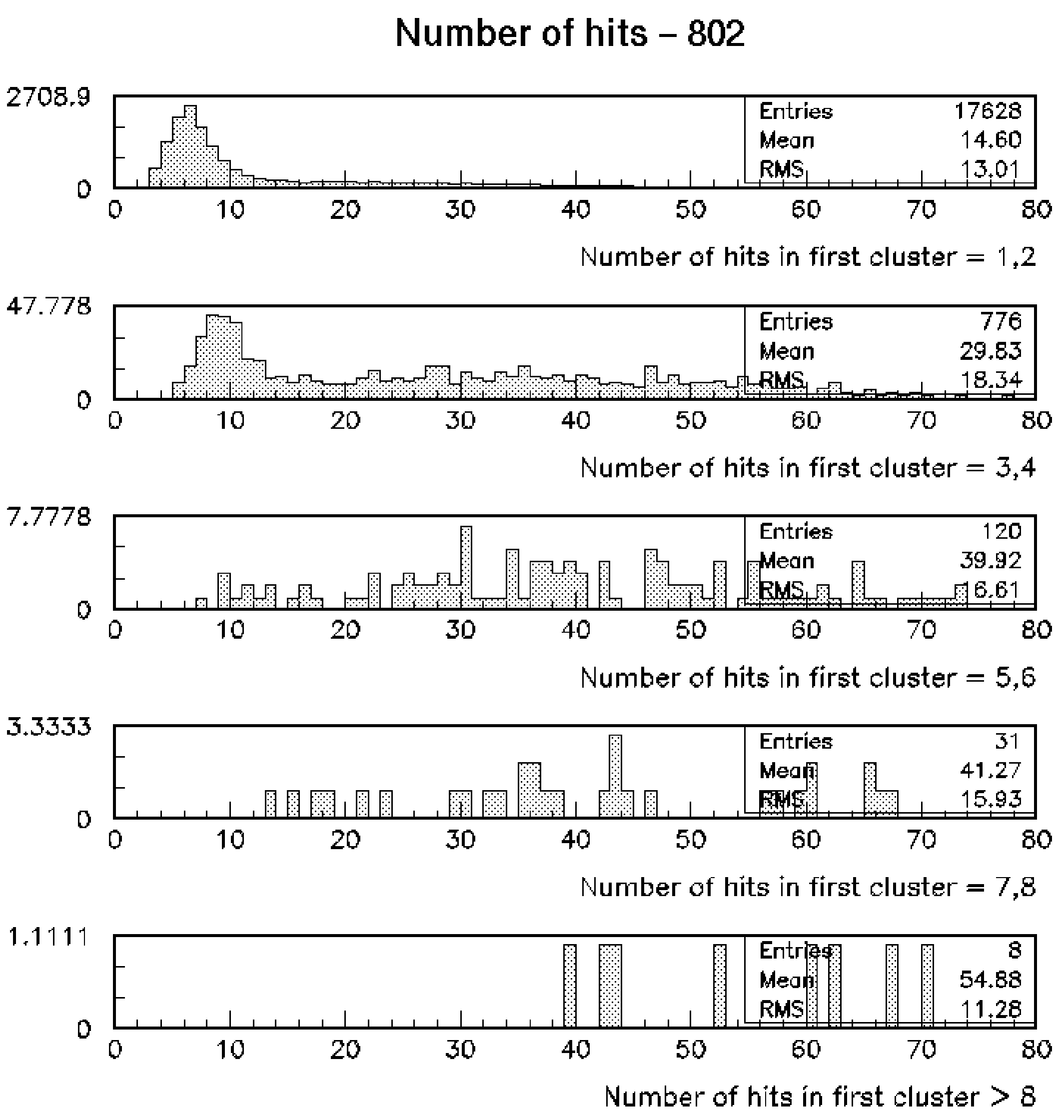
Significant leakage for R>5

(for e^+ also R>5)

Cluster in 1st layer: R = maximum distance in x or y from center of layer

Hits in first layer

Data selection:	Exactly one cluster in first layer Distance R< 5



Request no more than 4 hits

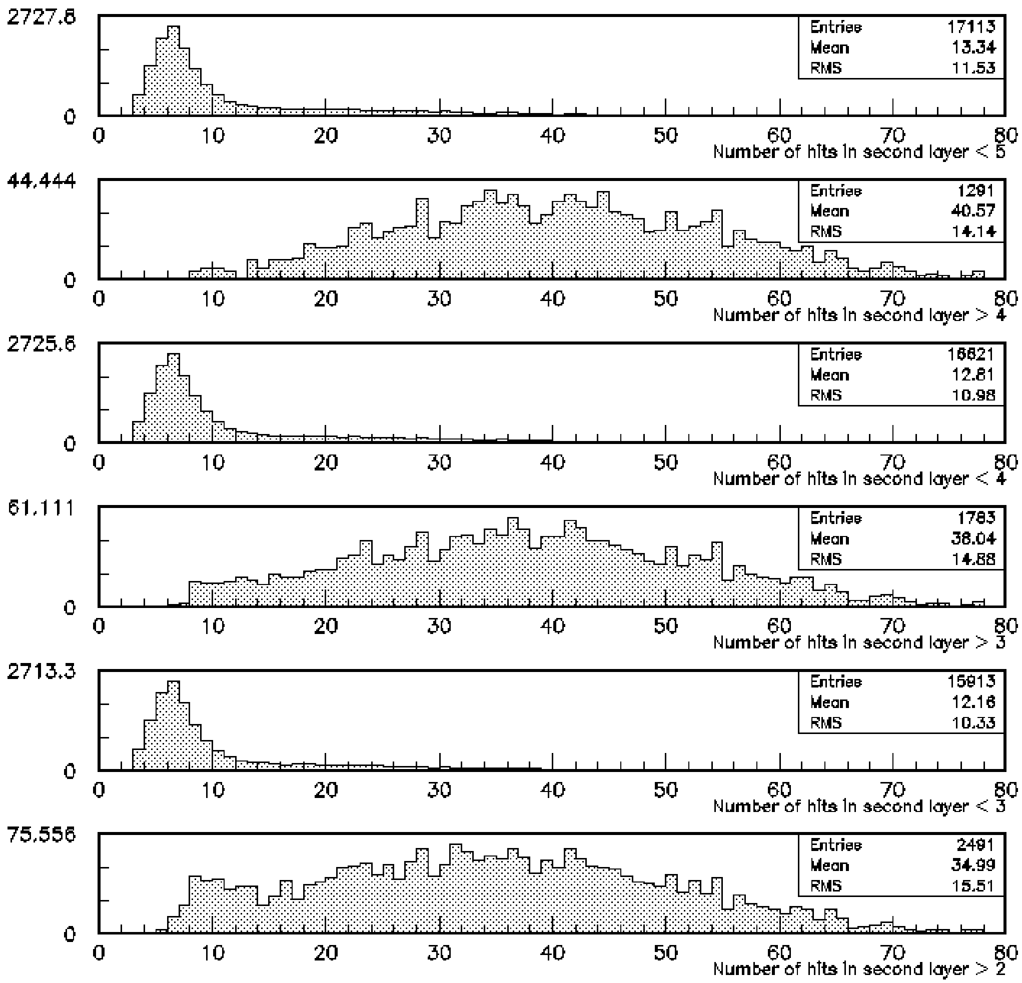
Only 158 events

Upstream hadronic showers

Hits in second layer

Data selection:	Exactly one cluster in first layer Distance R< 5 Number of hits in first layer <5

Number of hits – 802



Choose this one

To separate MIPs (μ,π) from π's which interacted early, but in the calorimeter

Hit distribution

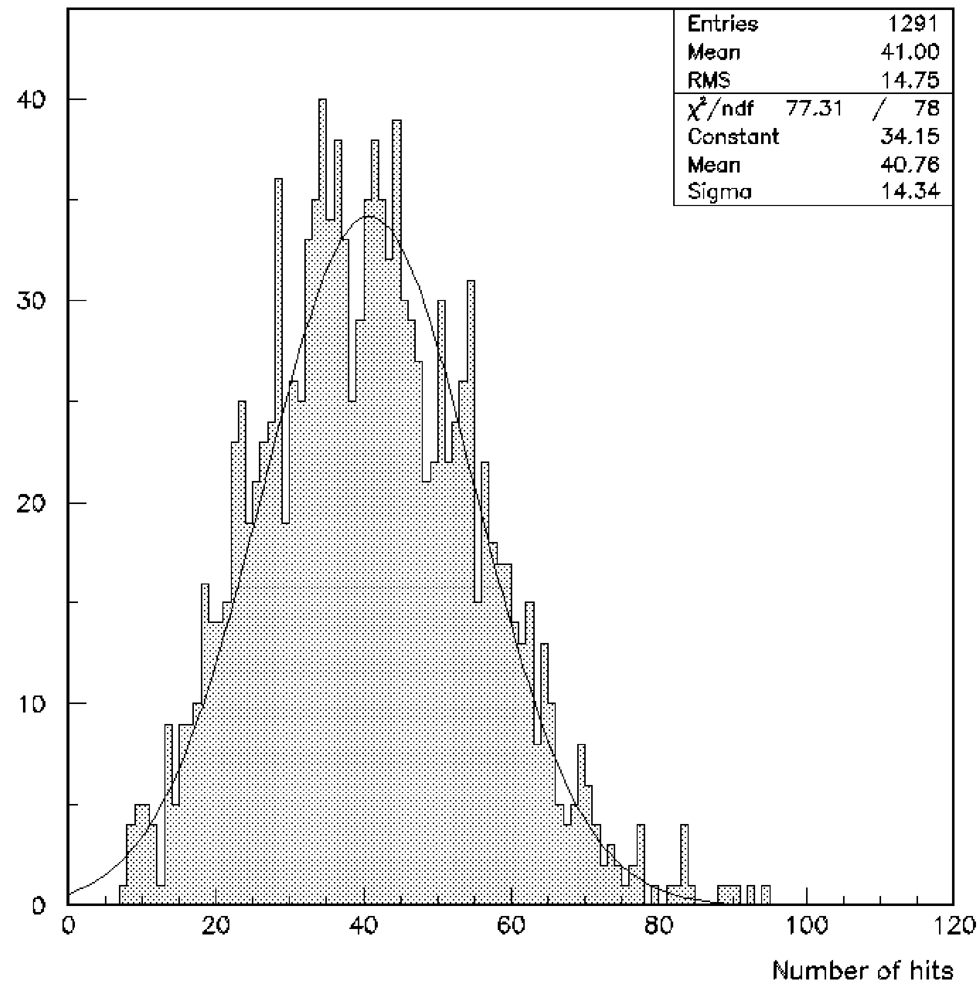
Data selection:	Exactly one cluster in first layer
	Distance R< 5
	Number of hits in first layer <5
	Number of hits in second layer >4

Almost perfect Gaussian

σ_E/E = 35.2 %

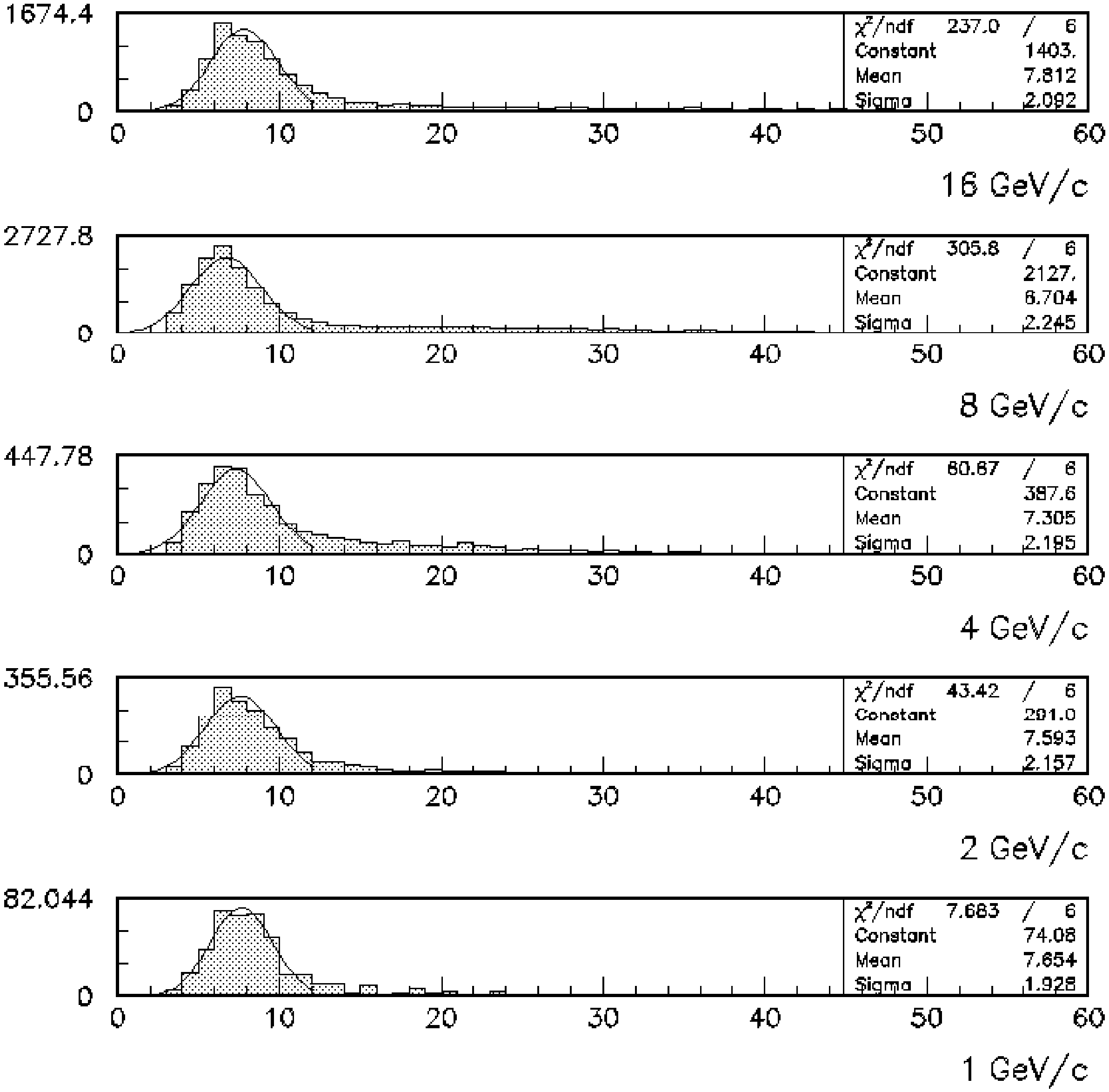
σ_E/E = 21.1 %
(for positrons)

Number of hits – 802



Hit distribution

Data selection: Exactly one cluster in first layer
Distance R< 5
Number of hits in first layer <5
Number of hits in second layer <5

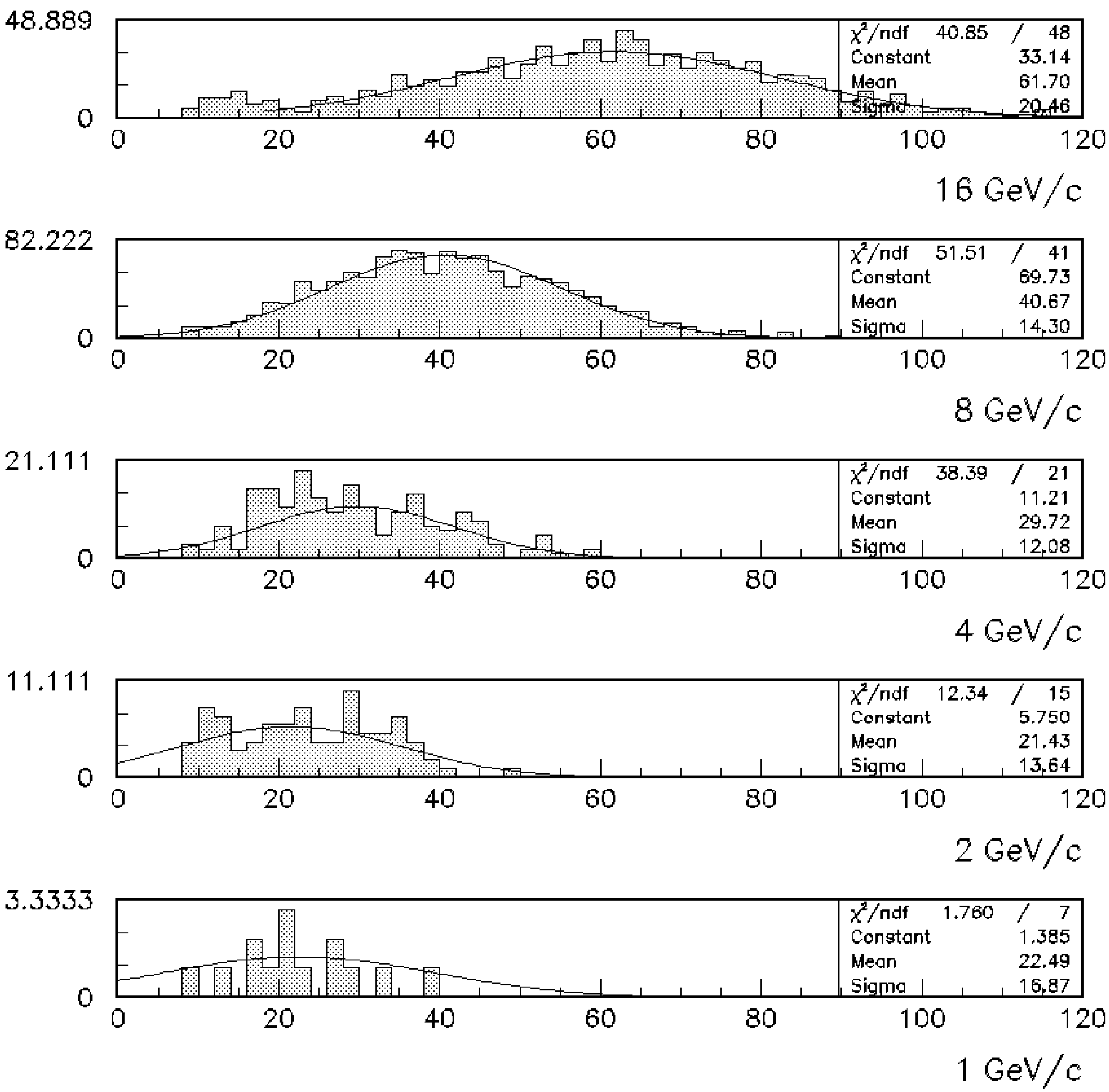


Nice MIP peaks

Some contamination from 'late' showers

Hit distribution

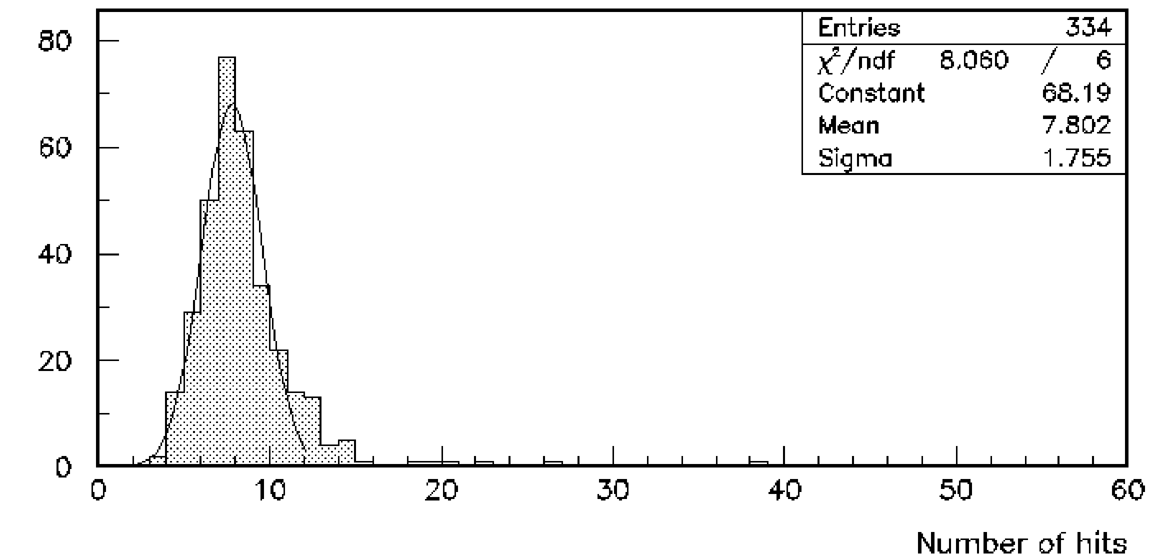
Data selection:	Exactly one cluster in first layer Distance R< 5 Number of hits in first layer <5 Number of hits in second layer >4



Some MIP contamination at 16 GeV/c

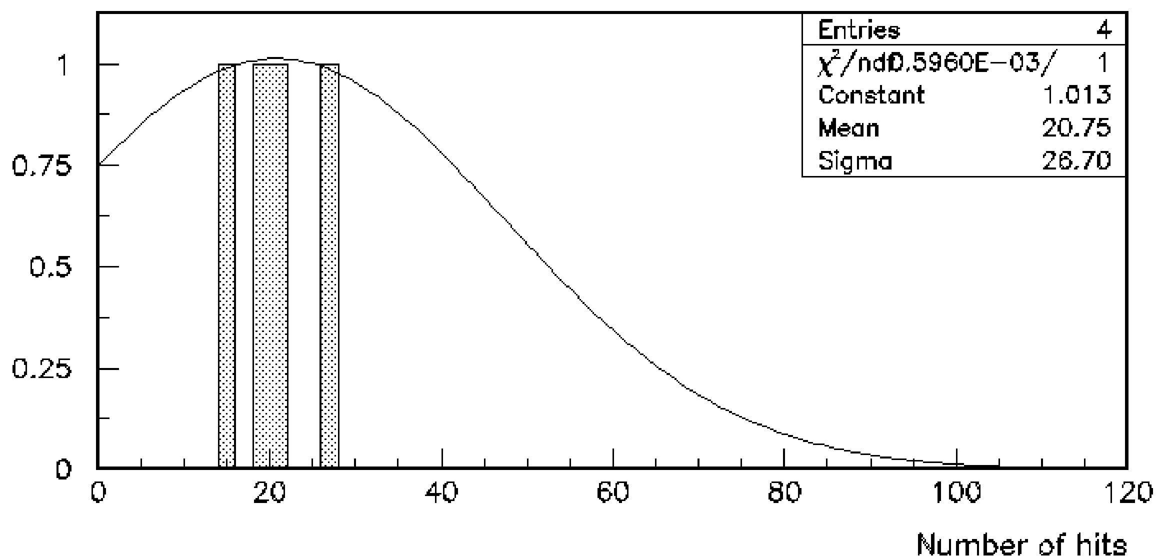
Not much data at 1 and 2 GeV/c

Brick run – Hit distribution



Data selection:

Exactly one cluster in first layer
Distance R< 5
Number of hits in first layer <5
Number of hits in second layer <5

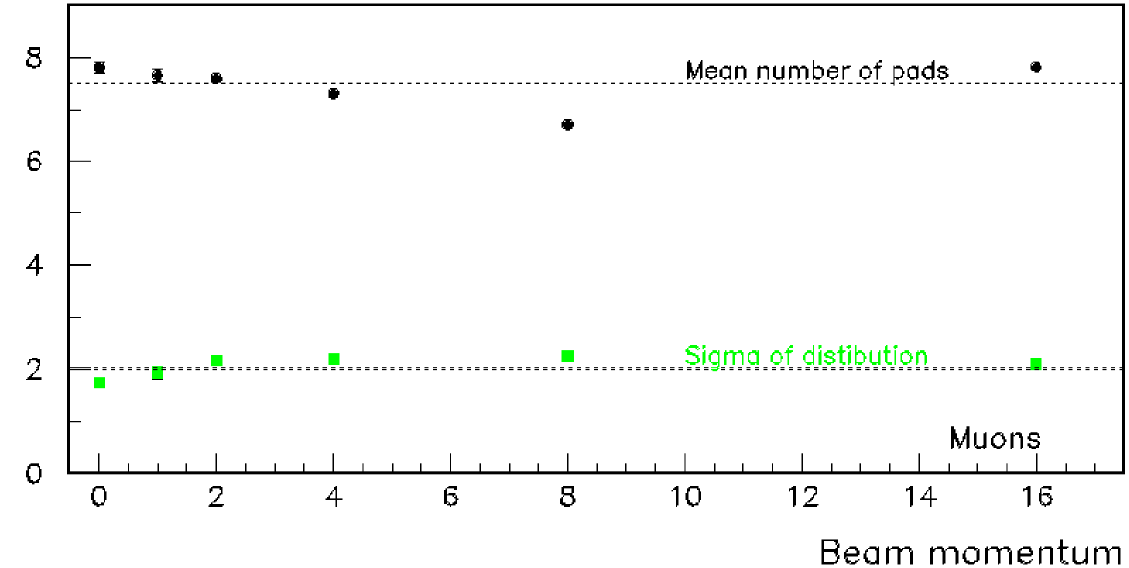


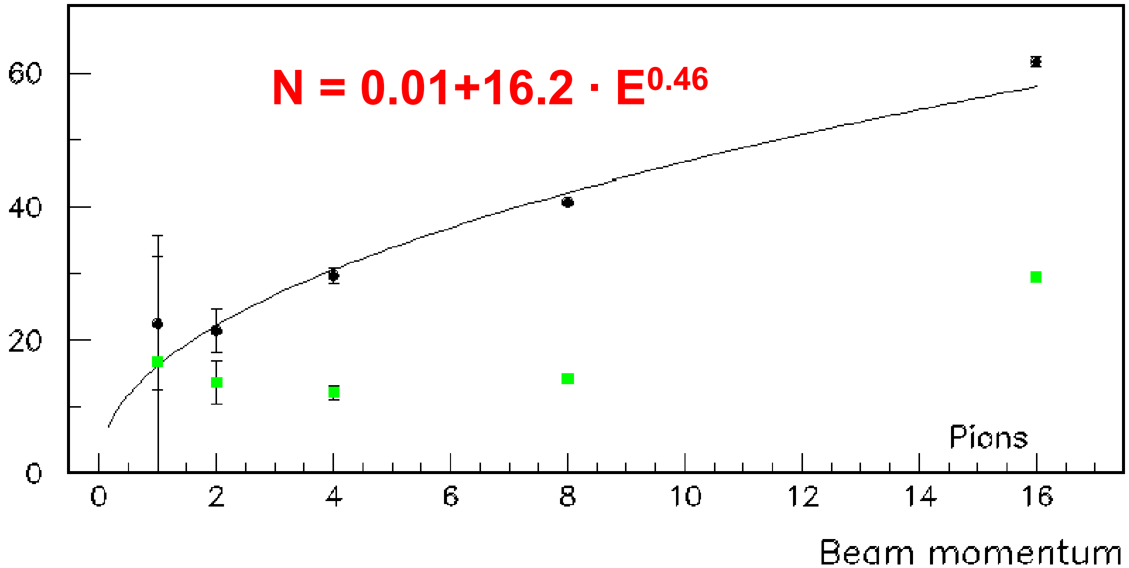
Data selection:

Exactly one cluster in first layer
Distance R< 5
Number of hits in first layer <5
Number of hits in second layer >4

As expected

Linearity – Resolution





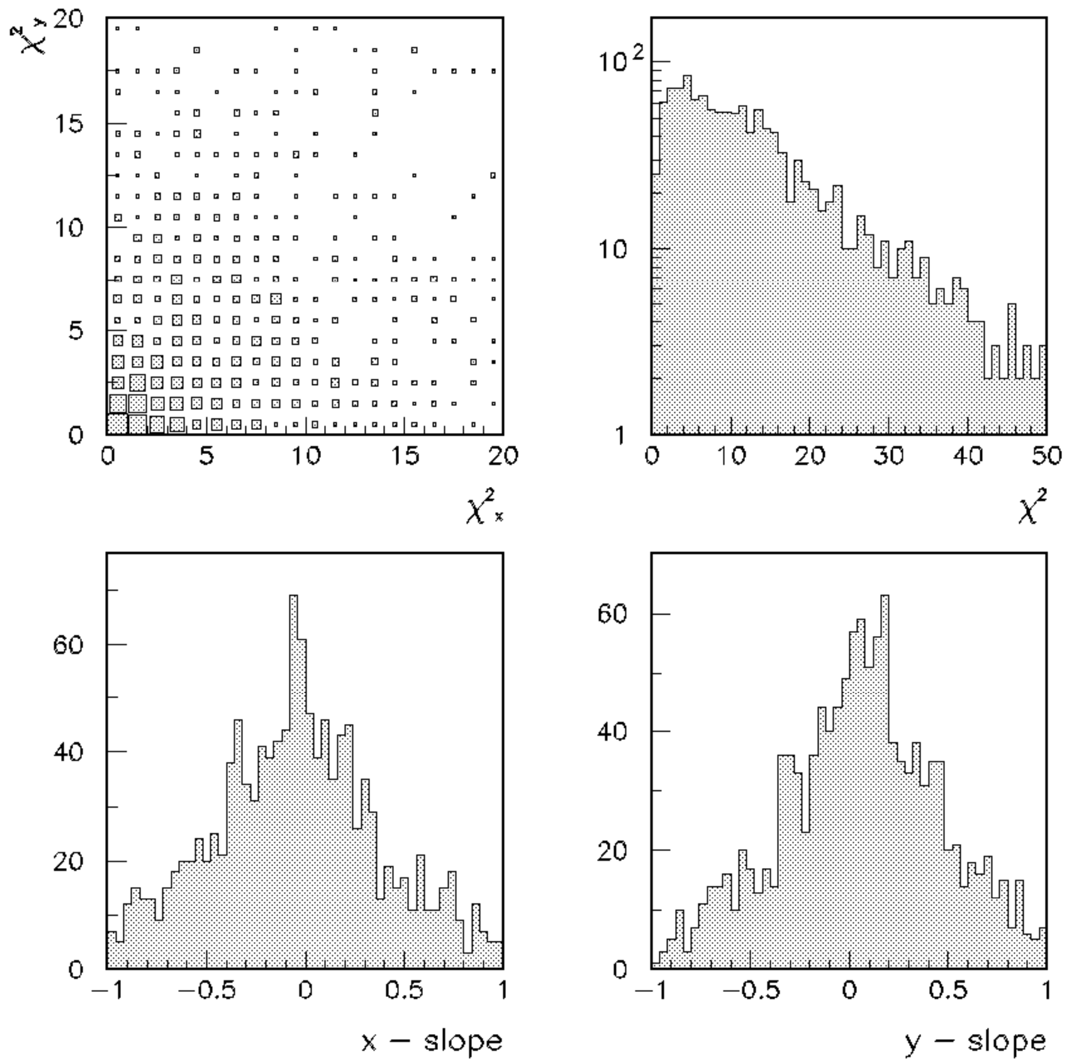
Reasonably stable

Brick run data shown at p = 0

$N = 0.01+20.24 \cdot E^{0.44}$
(for positrons)

Shower reconstruction – Pion selection

Calculate average x,y in each layer
Fit straight lines through average x,y positions

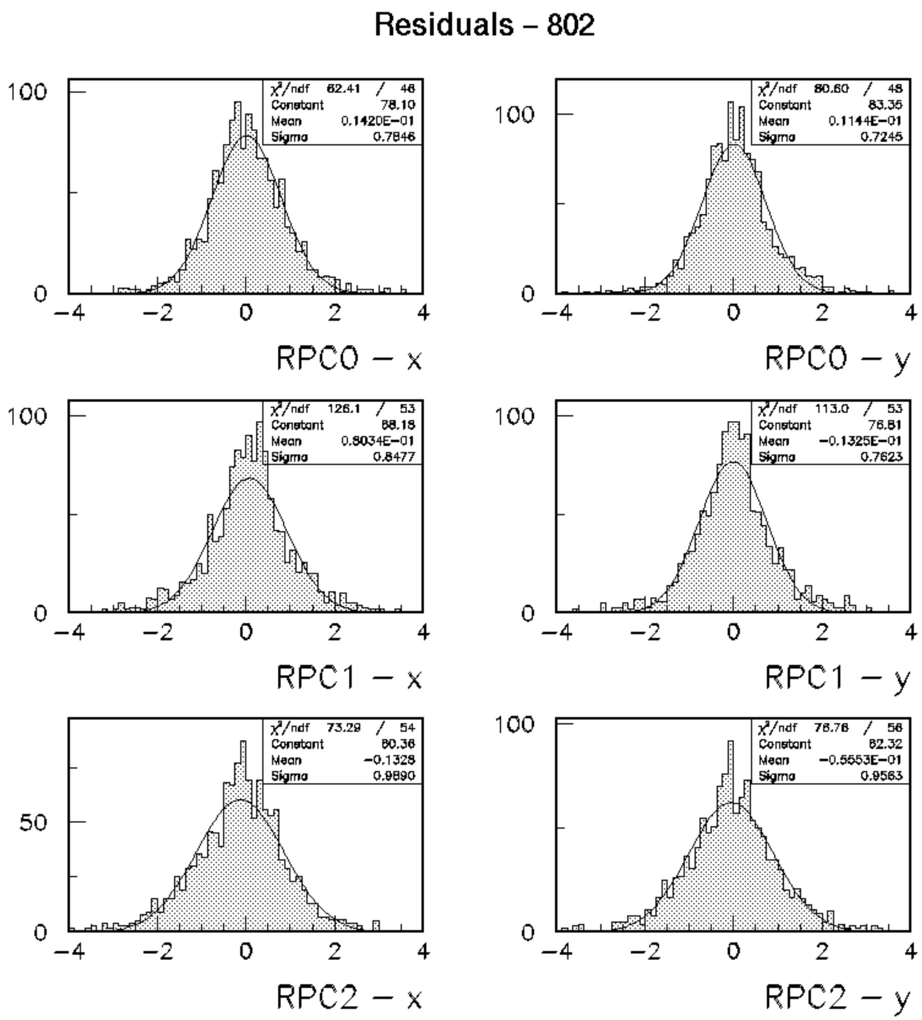


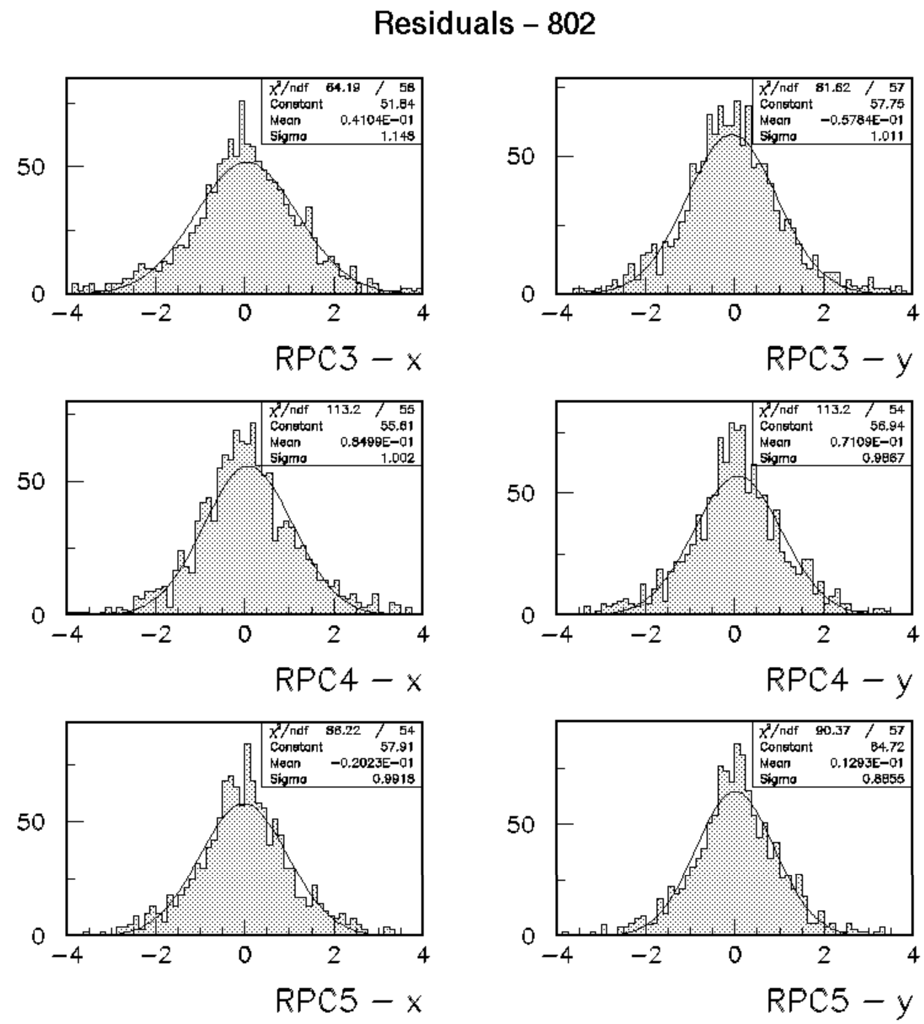
Fits not as good as for positrons

No correlation in χ^2

Slopes larger than for positrons

Shower reconstruction – Pion selection

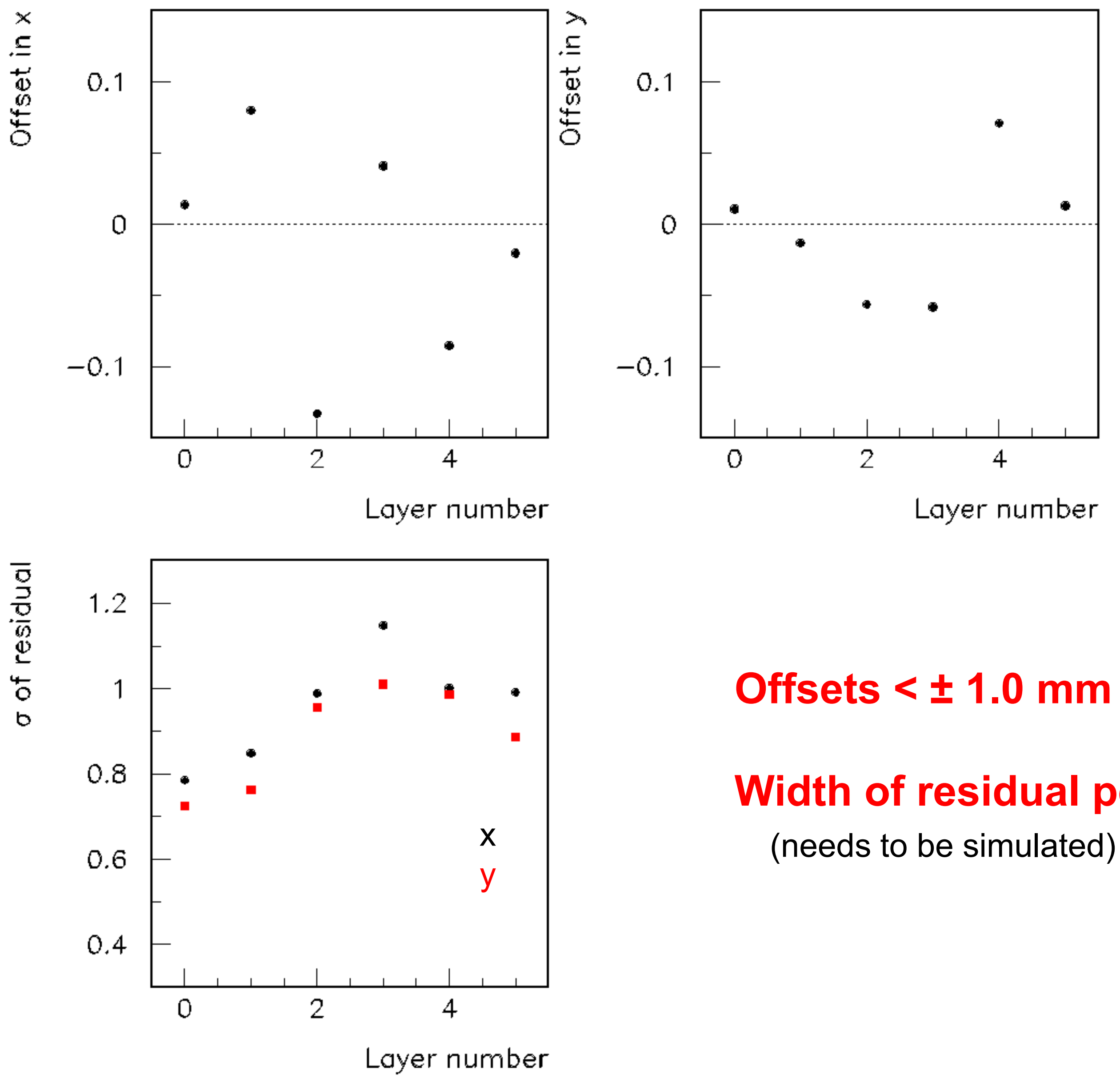




Δx or Δy in [cm]

Residuals reasonably small and well centered

Pion runs – Shower reconstruction – Pion selection

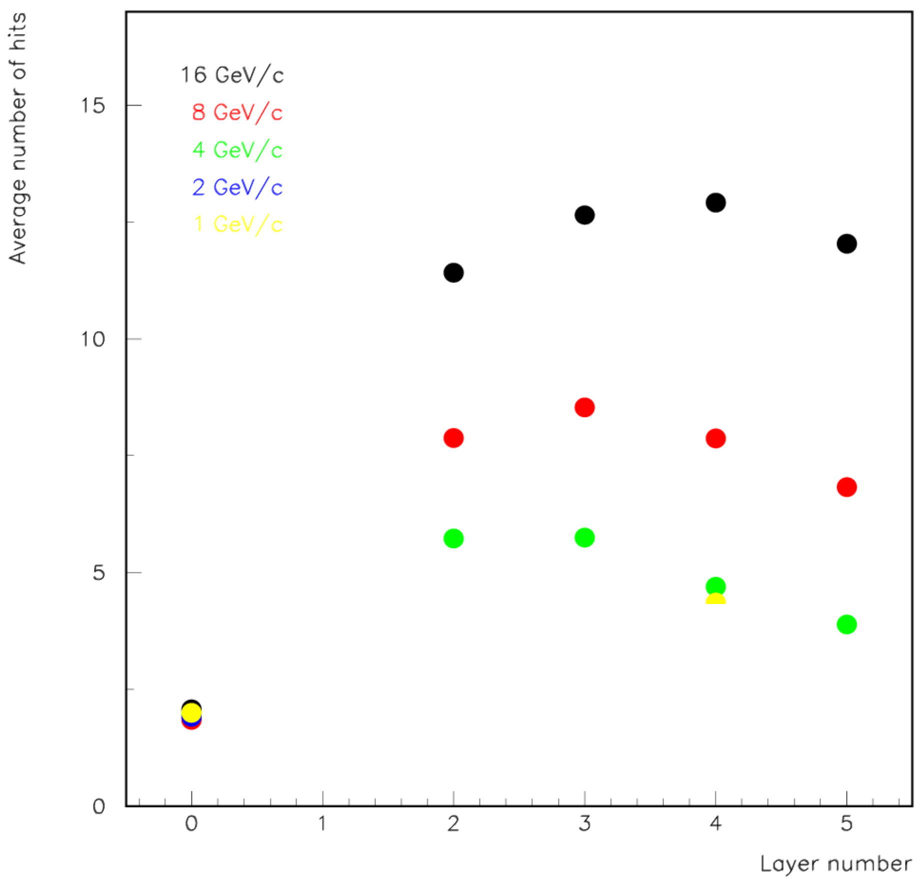


Offsets < ± 1.0 mm

Width of residual peaks at layers 3/4

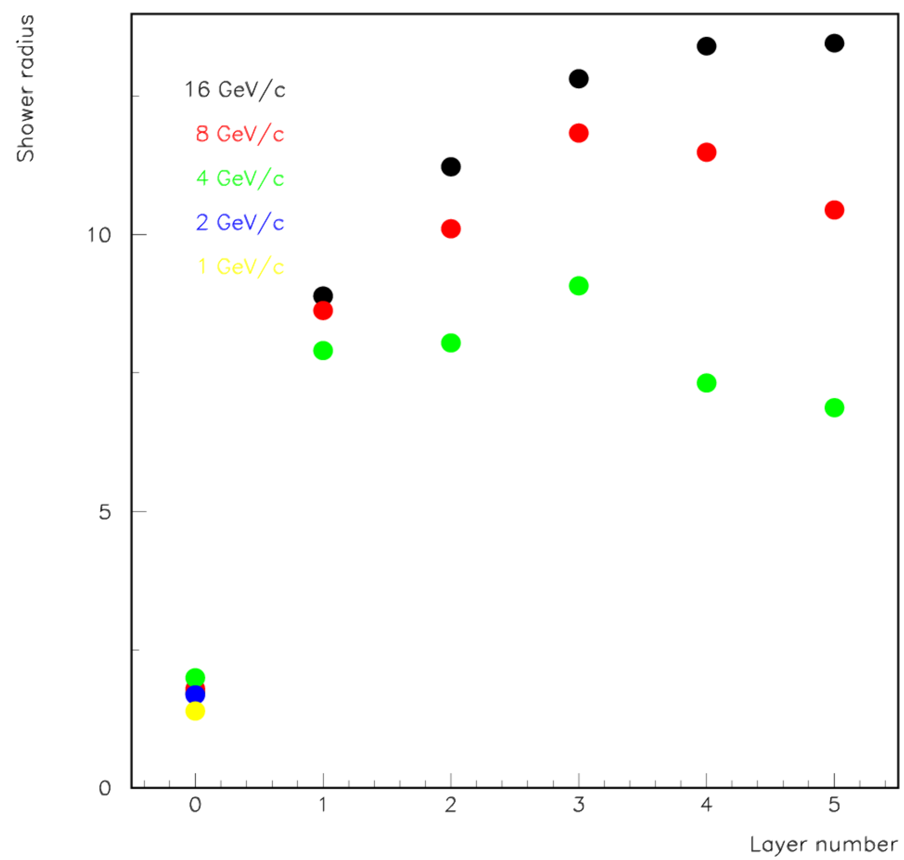
(needs to be simulated)

Pion runs – Average shower shape – Pion selection



Effect of cut on nhit>4 clearly visible for p ≤ 8

Statistics too poor for p ≤ 4



→ needs to be simulated

Monte Carlo Simulation

DHCAL Calibration procedure

Data (HV,THR) $\rightarrow \mu_0, \varepsilon_0$
Correction for actual μ_j,ε_j of layer j

$N_i^{DT} = \Sigma_{\text{layer } j}\, n_{i,j}\, (\varepsilon_0/\varepsilon_j)\, (\mu_0/\mu_j)$ i…event id

$\updownarrow$

$N_i^{MC}\, (\mu_0,\varepsilon_0)$

Reproduce hit distribution

a) Get x,y,z of each energy deposit in the active gap from GEANT4
b) [Filter hits if closer than R_0 (pick one of the hits randomly)]
c) Generate measured charge distribution
d) Distribute charge over pads assuming a black disk of radius R or
Distribute charge according to STAR-RPC measurement
e) Apply threshold T to flag pads above threshold (hits)
f) Adjust T,R to reproduce measured n_hit distribution
g) Compare T-dependence with measurement

Monte Carlo Input

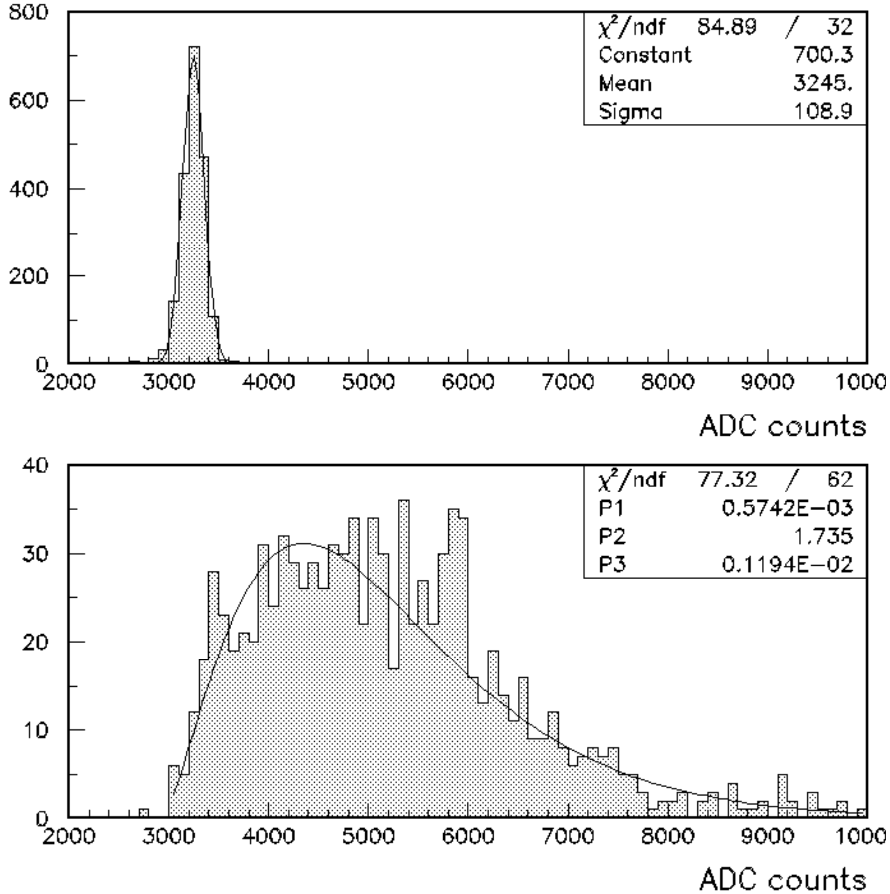
i_input = 1 … flat distribution over single pad

i_input = 2 … track through layers 0 – 5, evenly distributed over pad 8/8

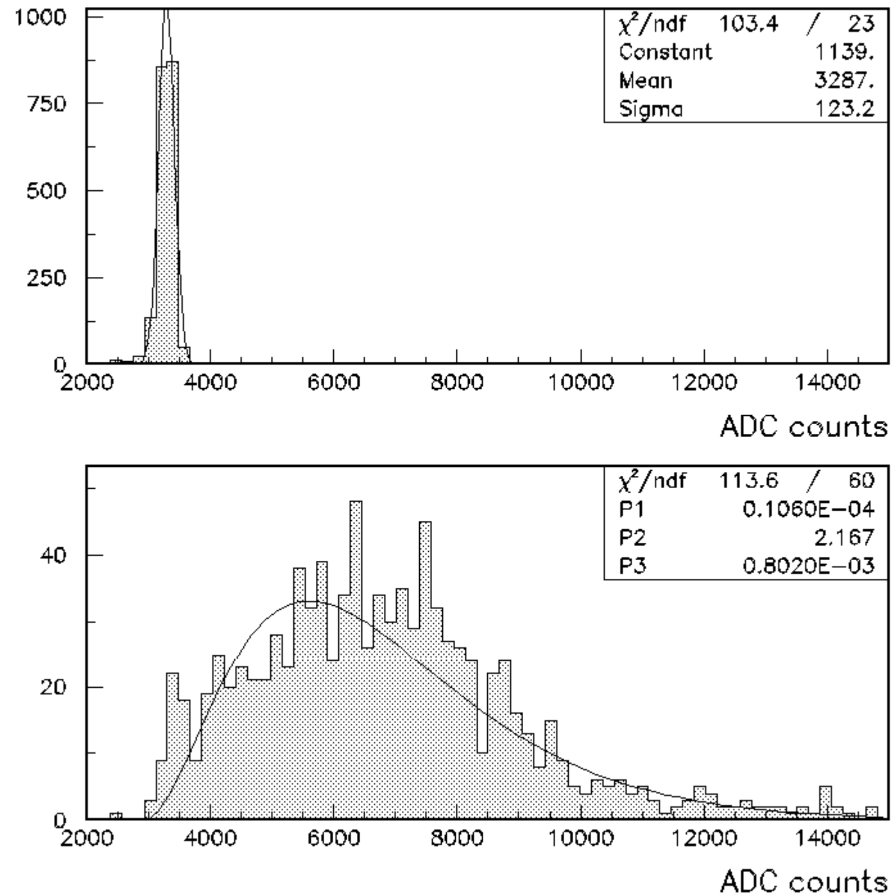
i_input = 3 … read data from file (output of GEANT4) ← **not yet available**

Charge spectrum – Fit to analog measurements

High Voltage = 6.2 kV



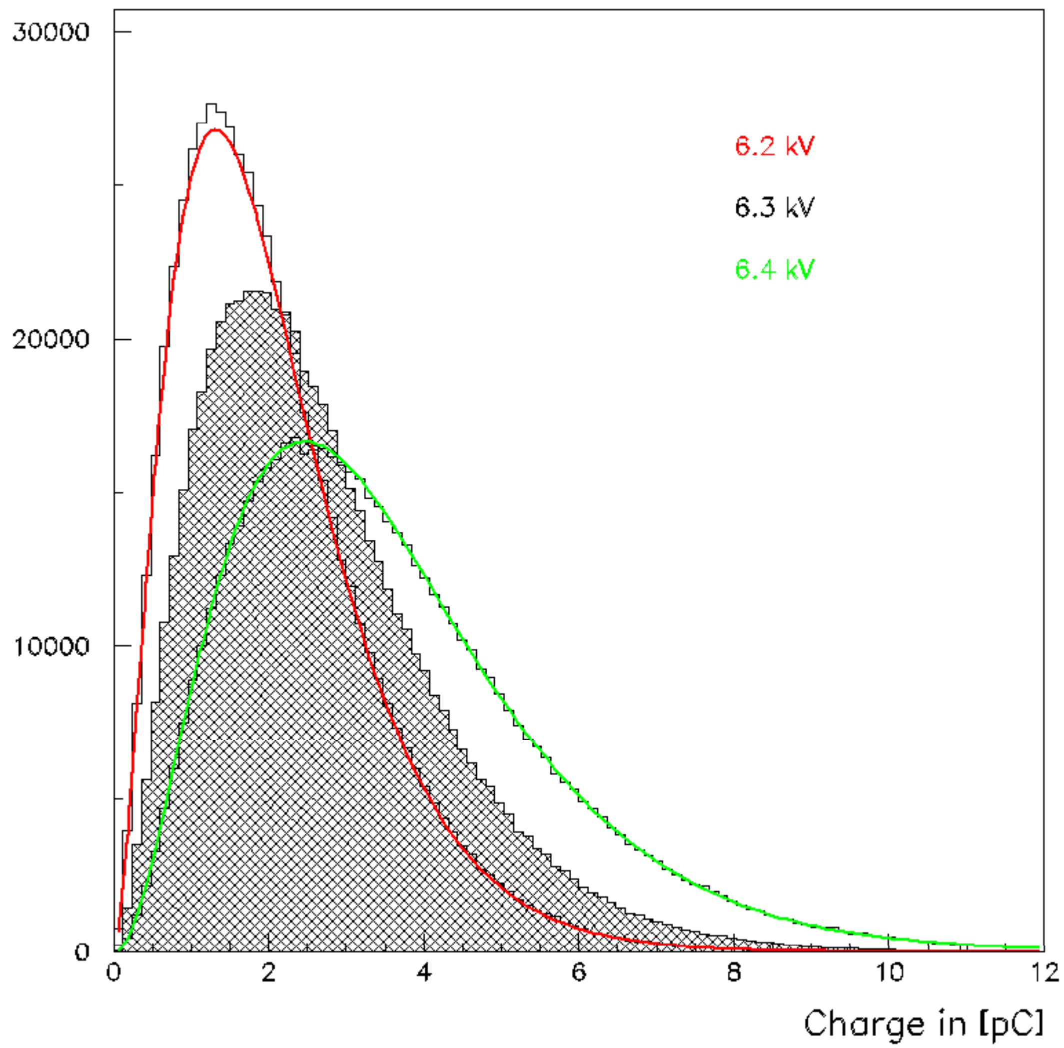
High Voltage = 6.4 kV



$$y = \alpha\, (x-2900)^{\beta}\, e^{-\gamma(x-2900)}$$

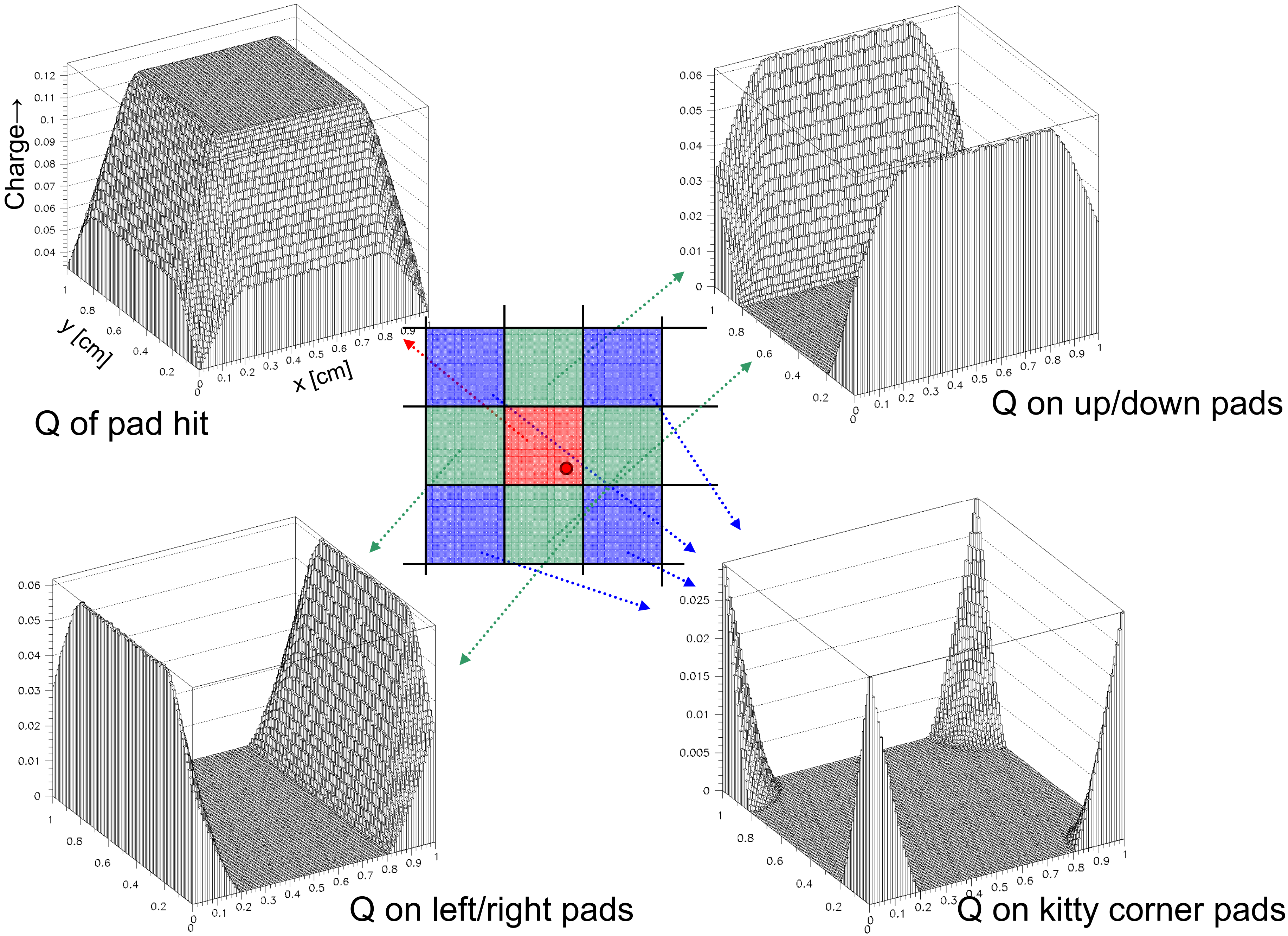
Pion data at 6.3 kV

Charge spectrum – Implementation into Program



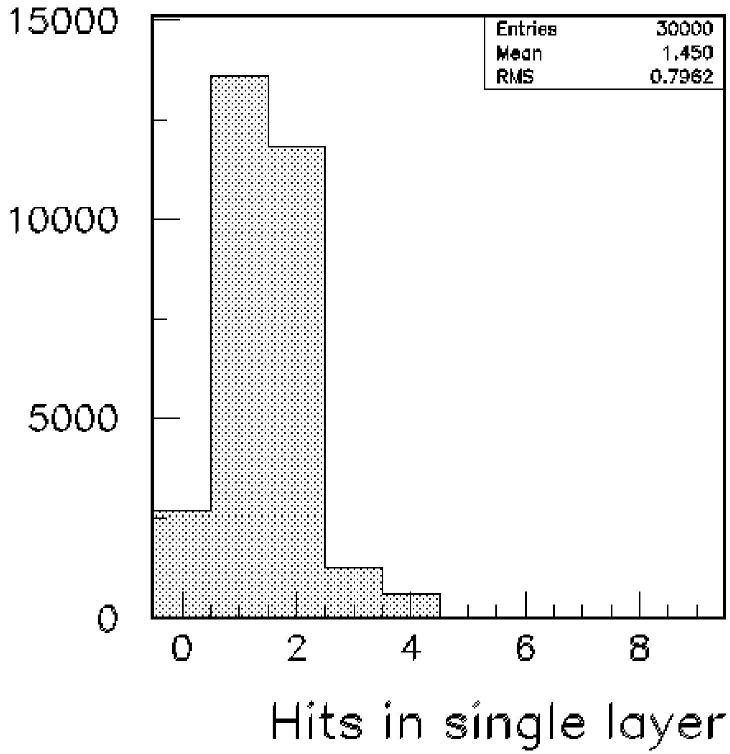
Charge spectrum at 6.3kV interpolated

Charge distribution - Black disk with R = 0.2 cm

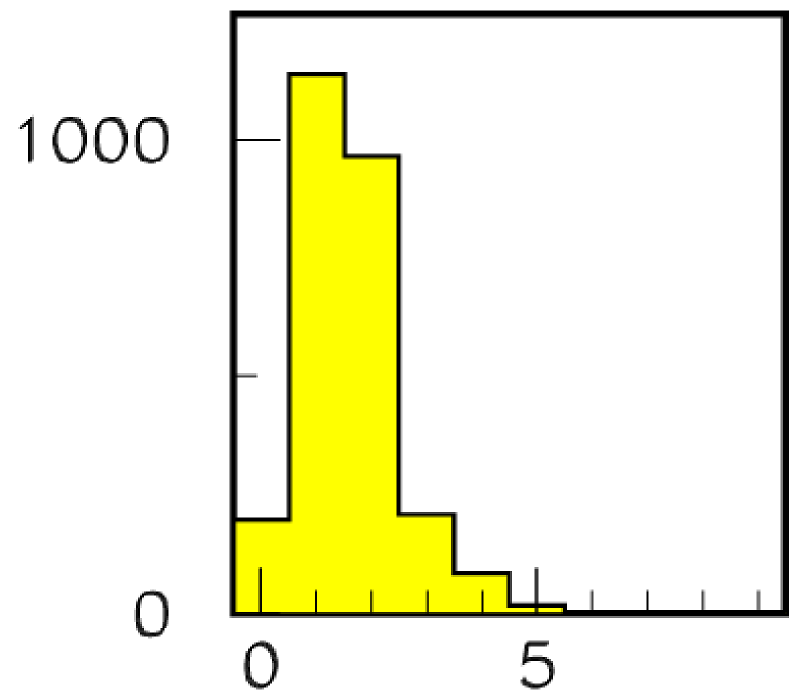


Black Disk Optimization

MC simulation



Data – RPC2



Can reproduce pad multiplicity and efficiency with

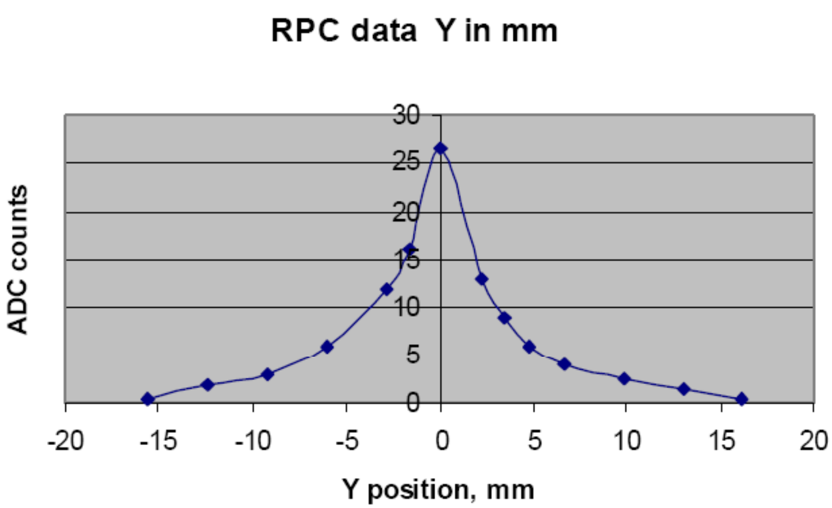
R = 0.45 cm and T = 0.55 pC

→ R ~ 0.2 cm and T ~ 0.2 pC would have made more sense

Charge Distribution – Exponential dependence

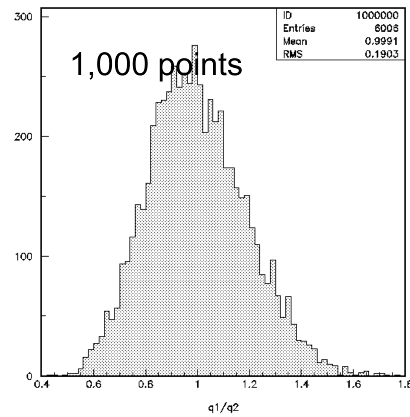
Star - RPC paper (IEEE)

Glass t = 1.1 mm
Gas gap = 1.1 mm
Gas identical to us
} similar to us
Measurement of charge distribution

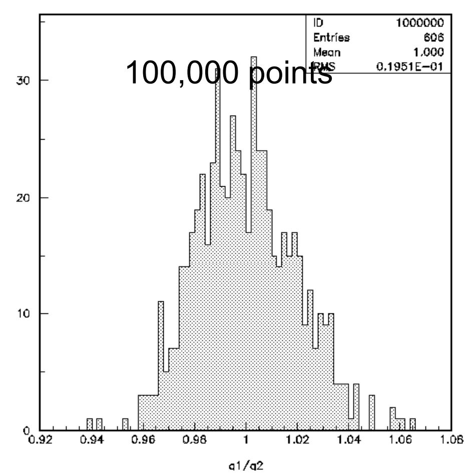


Distribute charge using MC method

Generate points randomly within R < 3 cm
Calculate Q(R)
Deposit on corresponding pad



← RMS of 20%

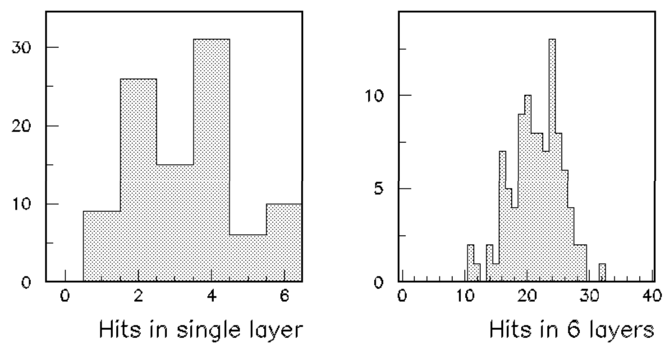


RMS of 2% →

(sufficient)

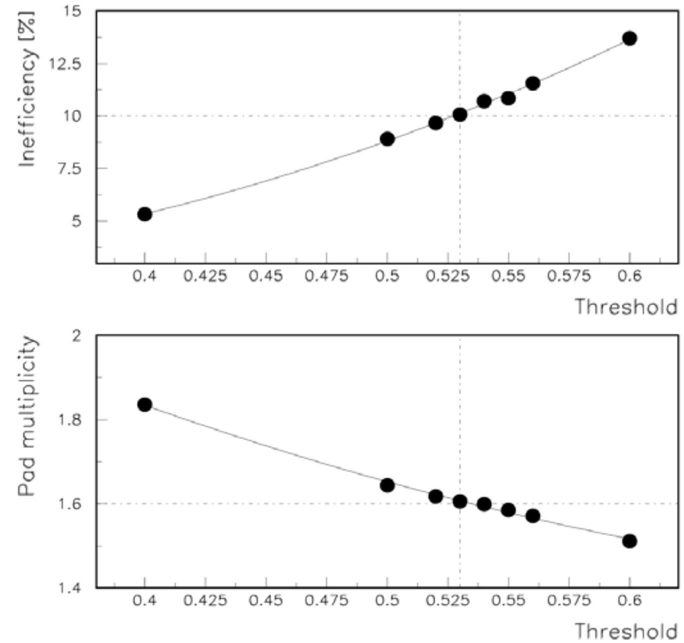
Hit distributions

a = 0.333 T = 0.17

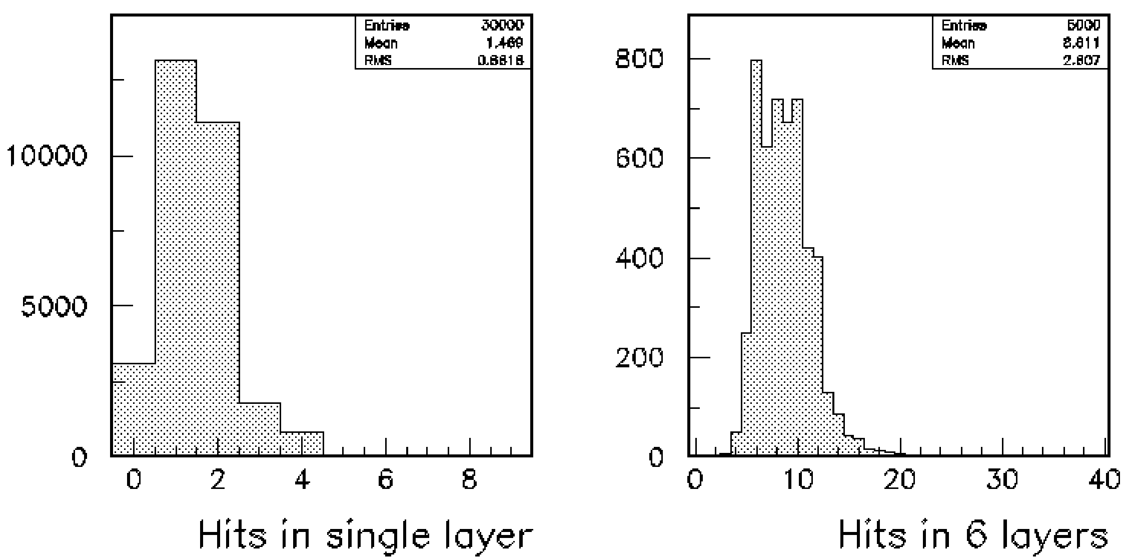


Default parameters

Slope = 0.200

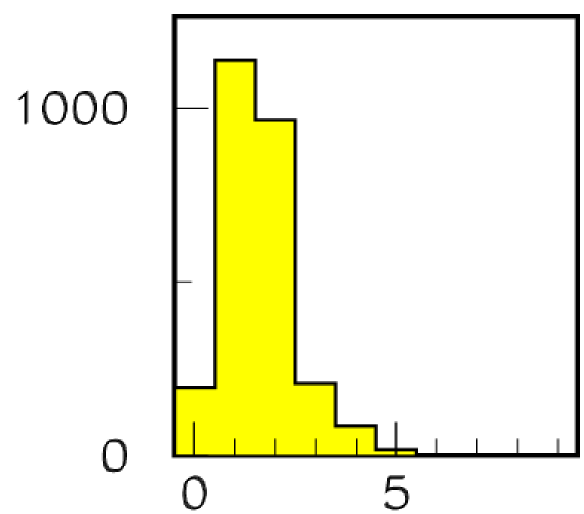


a = 0.200 T = 0.530

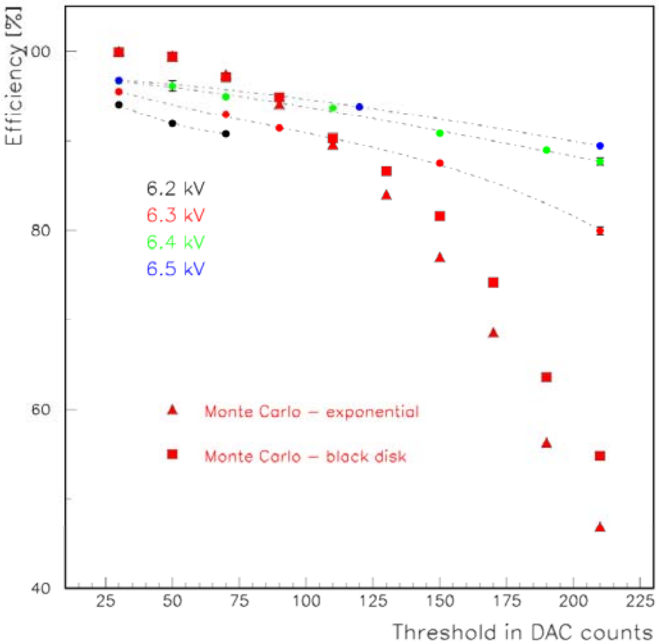


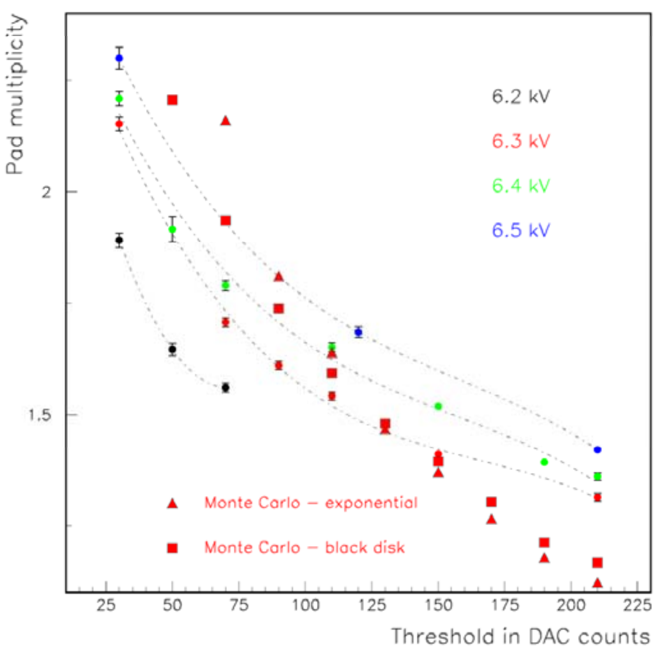
Optimized parameters

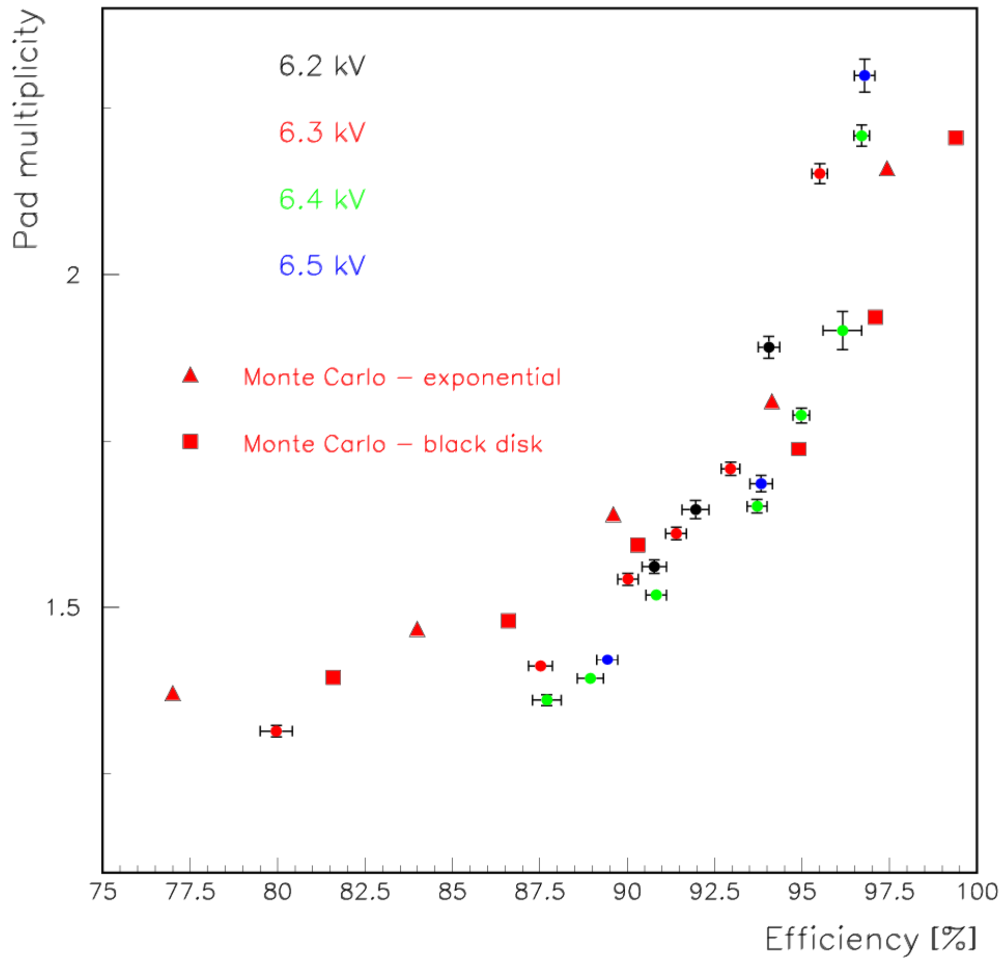
Data – RPC 2



Trying out different thresholds







Does not work too well
Black disk actually a bit better

Conclusions

Pion analysis

Data mostly understood
Separation of MIPs (μ,π) and 'early, but not too early' hadronic showers possible
Some crude measurement of shower shapes

Monte Carlo simulation

Almost ready
Not clear why simulation of avalanches different from expectation

Soon

Comparison with simulation
Estimate of pion rate in beam

Concept of a RPC-DHCAL validated